

Reasoning with Visual Depictive Representations

Soar Spatial & Visual Imagery (Soar+SVI)



OUTLINE

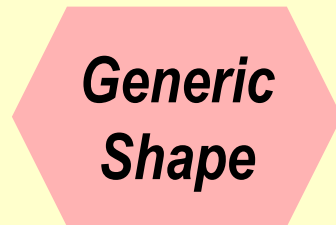
- **BACKGROUND**
- **MOTIVATING EXAMPLE**
- **DEPICTIVE MANIPULATIONS**
- **RESULTS**
- **NUGGETS / COAL**

WHAT IS MENTAL IMAGERY?

MENTAL IMAGERY

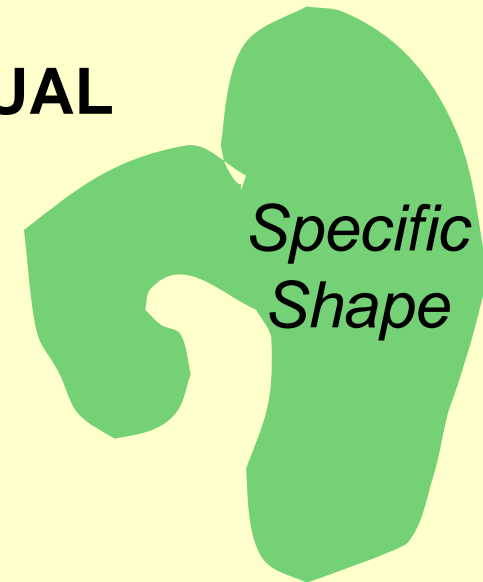
SPATIAL

- Direction
- Distance
- Orientation
- Size
- Topology



VISUAL

- Features
- Color
- Spatial



WHY RESEARCH MENTAL IMAGERY?

- **Cognitive Architectures**

- Amodal, symbolic representations & computations
- Little **reasoning** with perceptual-based representations (Barsalou 1999, 2008)

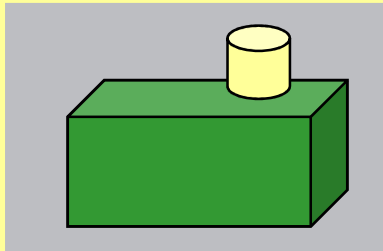
- **Resulting in...**

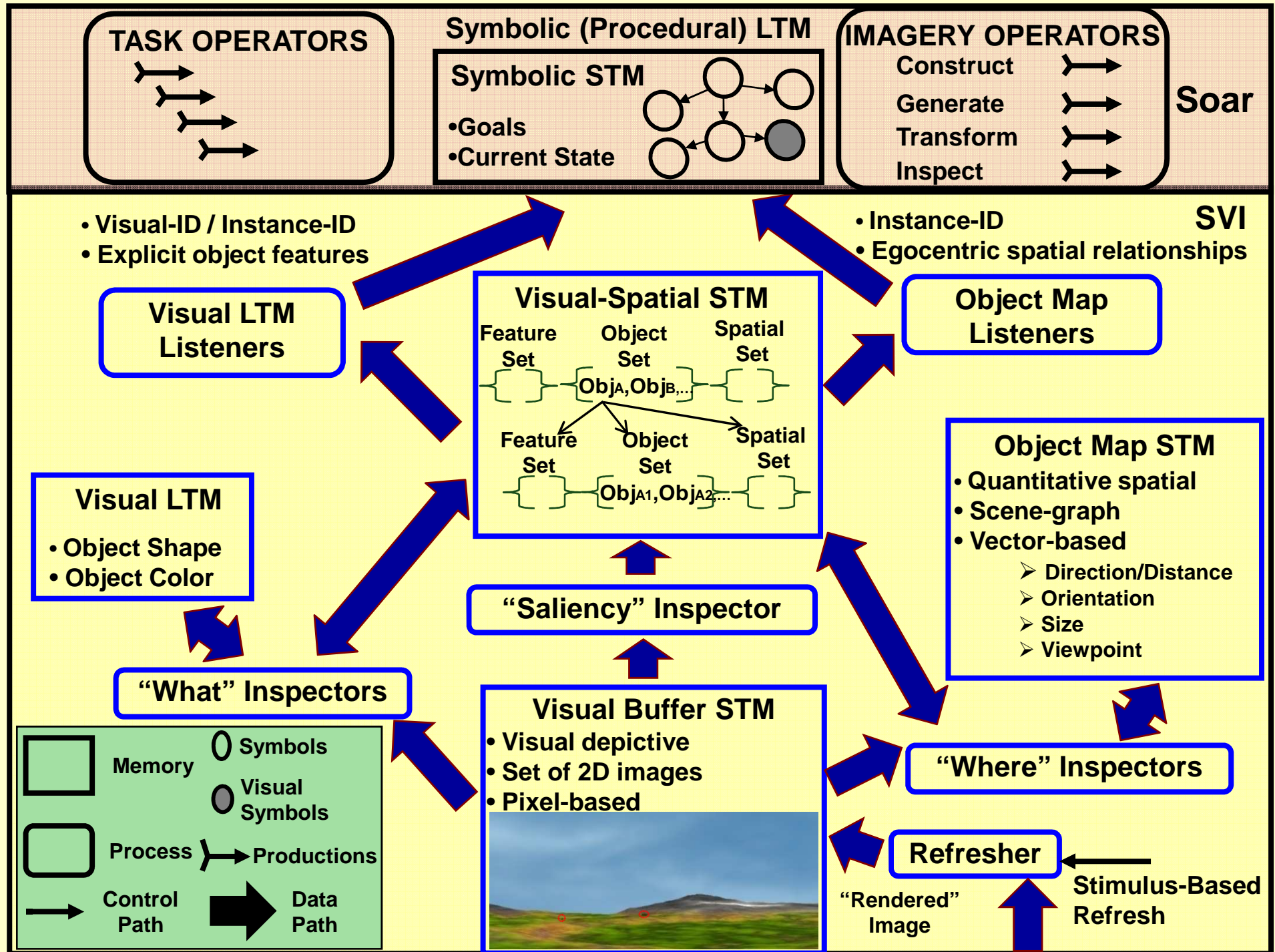
- Ad-hoc reasoning in tasks rich with spatial and visual properties
- “Bolted-on” task-dependent components

- **What we want**

- Link **perceptual-based thought** and **cognition**
- “Best of both worlds” **multi-representational**, task-**independent** approach
 - Additional functionality
 - Computational advantage

IMAGERY REPRESENTATIONS

Representation	Processing	Uses	Example
<p><i>Symbolic</i></p> <p>Amodal</p>	<p>Symbolic manipulation</p>	<p>General Reasoning</p> <p>Qualitative Spatial & Visual Reasoning</p> <p>Control imagery operations</p>	<p>object(can) feature (can, curve) color(can, yellow)</p> <p>object(box) feature(box, corner) color(box, green)</p> <p>on(can, box)</p>
<p><i>Quantitative spatial</i></p> <p>Amodal/Perceptual-based</p> <p>(Spatial Imagery)</p>	<p>Mathematical manipulation</p> <p>Laws of Dynamics (motion models)</p>	<p>Spatial Reasoning (Generic Shapes)</p> <p>Facilitate building visual depictive representation</p>	<p>can location <2,1,2> orientation 0 height 5 radius 2</p> <p>box location <0,0,0> orientation 0 length 10 width 6 height 4</p>
<p><i>Visual depictive</i></p> <p>Modal/Perceptual-based</p> <p>(Visual Imagery)</p>	<p>Mathematical manipulation</p> <p>Depictive manipulation</p>	<p>Spatial Reasoning (Specific Shapes)</p> <p>Visual Feature Recognition</p>	



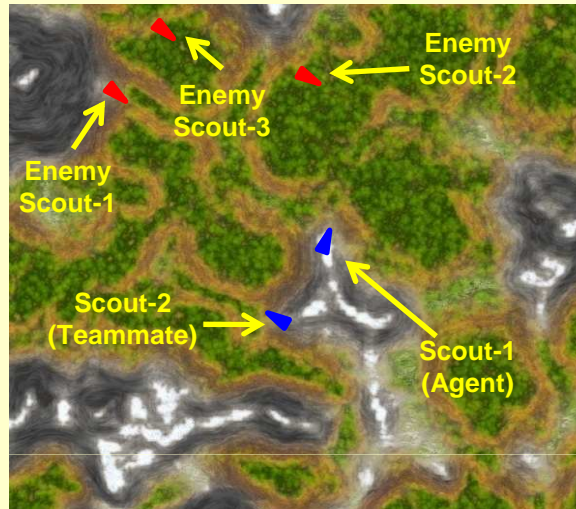
SCOUT DOMAIN

• Two scouts

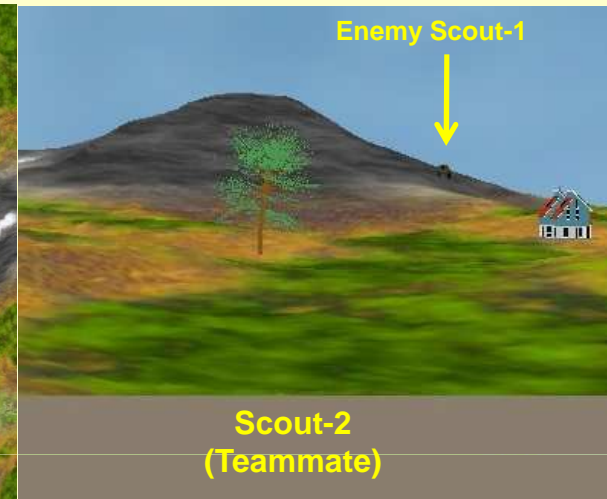
- Leader (Agent)
- Teammate (Scripted)
- Goal: maintain visual contact with approaching enemy to “paint picture”

• Task Characteristics

- Spatial (e.g. relationships between entities, terrain, etc.)
- Visual (e.g. terrain topological shape)
- Perceive/Imagine/Re-perceive
- Planning during execution
- Merge multiple sources of information (visual, messages, doctrine)



Actual Situation

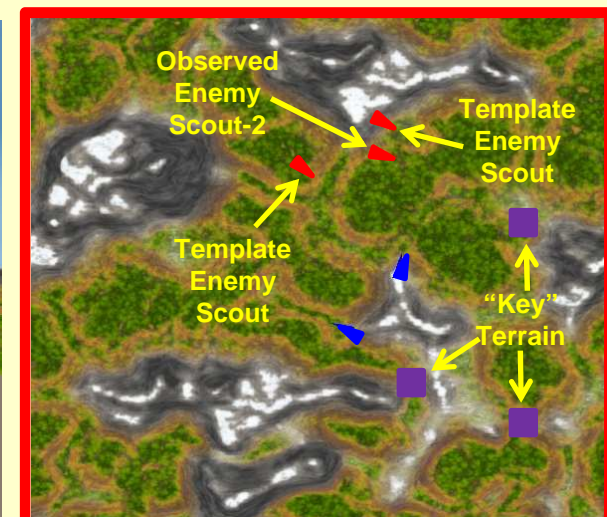


Teammate's View

Percepts	Actions	Task Knowledge
<ul style="list-style-type: none"> • Agent's location and orientation • Objects • Egocentric direction & distance • Messages from teammate 	<ul style="list-style-type: none"> • Look-at scene / map • Send message • Turn 	<ul style="list-style-type: none"> • Enemy doctrine • No-go/go terrain (pixel values) • Hypothesized key terrain

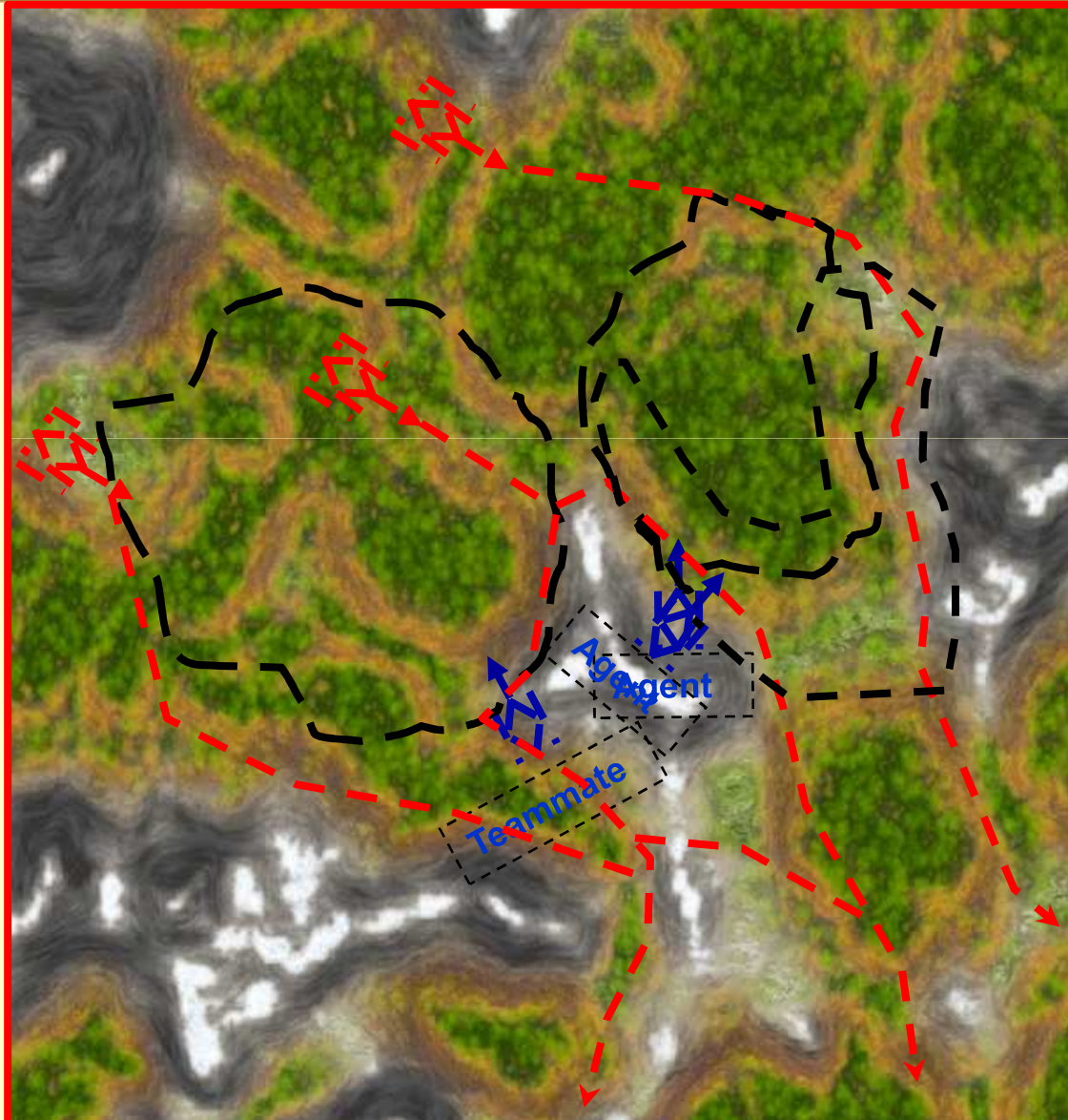


Agent's View



Imagined Situation ⁷

SCOUT DOMAIN (Example)



- Agent imagines what it and teammate can see (field of view)

LEGEND:

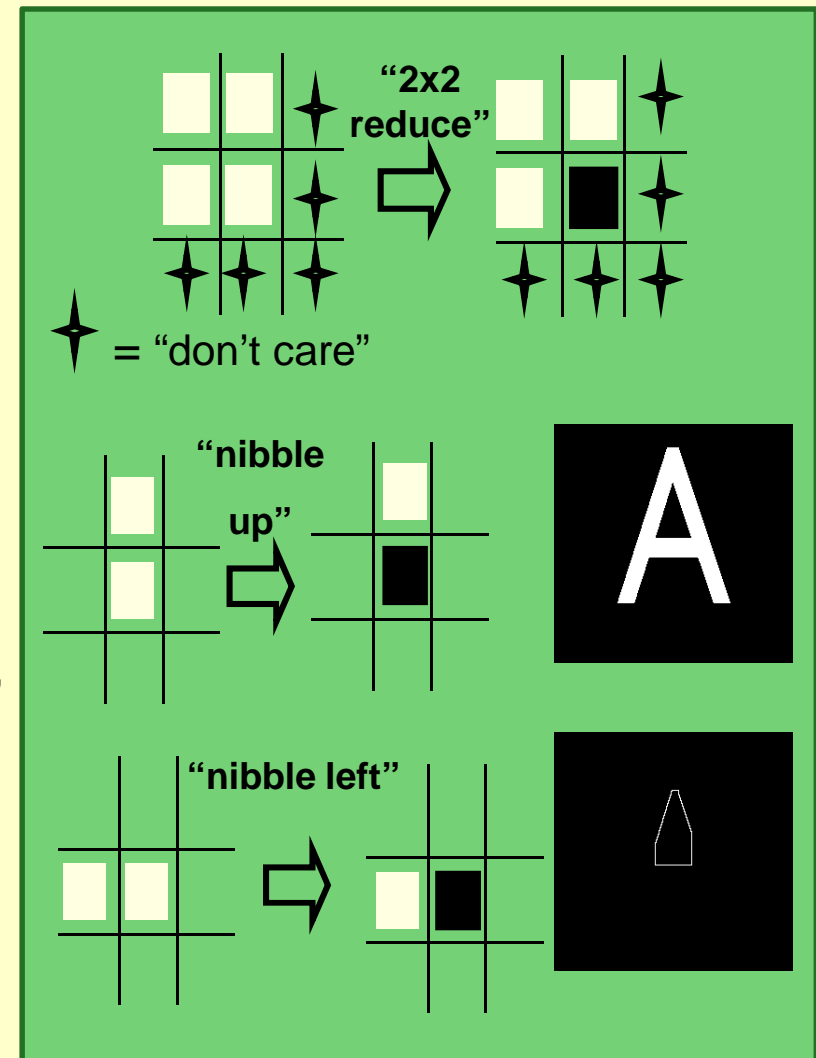
	Scout		Enemy
--	-------	--	-------

DEPICTIVE MANIPULATIONS

(1 of 2)

- **Pixel-level rewrites (Furnas)**
 - Production-like rules (LHS/RHS)
 - Shared image (i.e. working memory)
 - LHS and RHS are pixel patterns
 - Conflict resolution scheme (sequencing)
 - Processing may match other orientations
 - Active manipulation of shapes

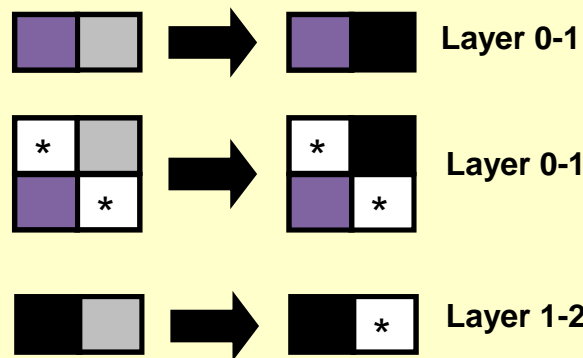
- **Contrast with other image processing**
 - Computer vision
 - Sentential manipulations
 - Filters (e.g. Gaussian) where each pixel is rewritten as a specific function of its neighbors' values
 - Cellular Automata
 - Finite State Machines
 - Next state of a cell based on current state and state of its neighbors
 - Rather than rewriting many local configurations at once



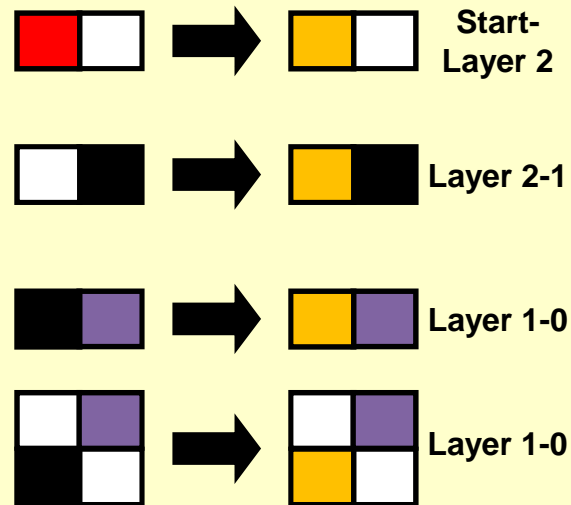
DEPICTIVE MANIPULATIONS

(2 of 2)

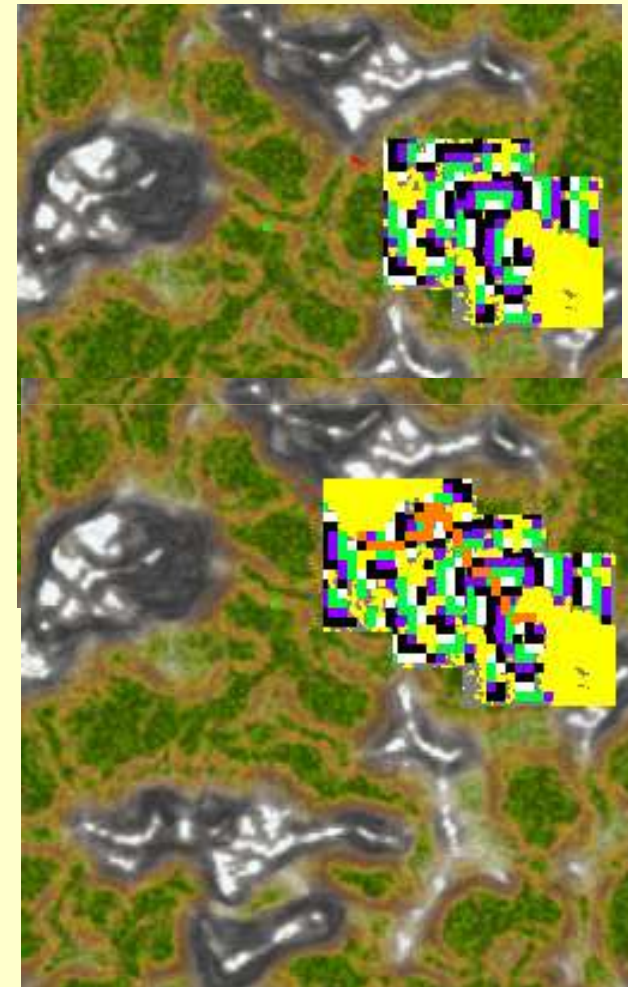
Distance Field Flood



Mark Path



- Takes specific shape of no-go terrain and obstacles (yellow) into account
- Attention window shift controlled by Soar
- Rules sent from Soar to manipulator via operator elaborations
- Determine approximate path coverage by overlaying each scout's view frustum
- Simulate alternate view orientations to determine "best" path coverage

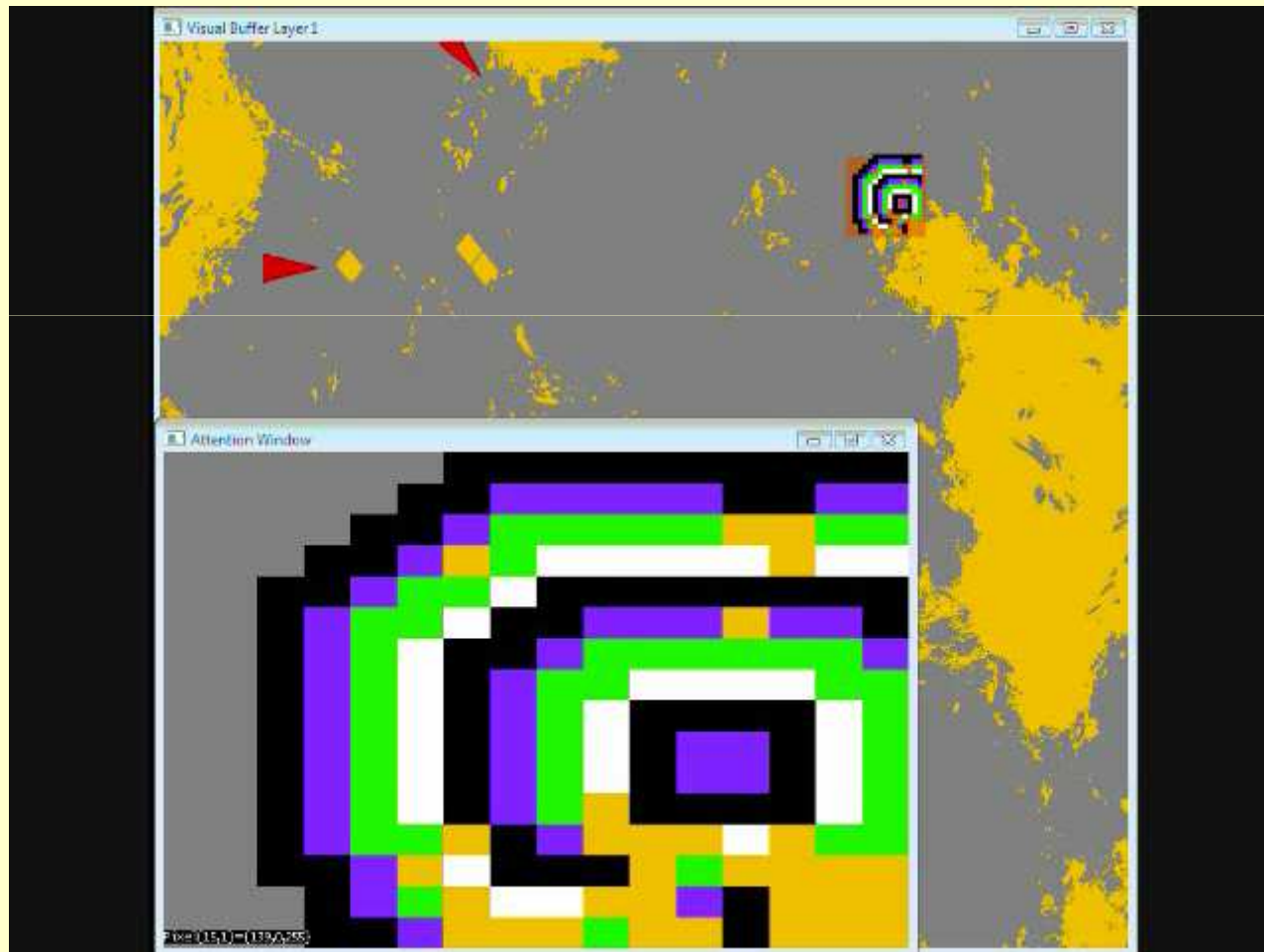




DEPICTIVE MANIPULATIONS (Soar only)



(VIDEO)

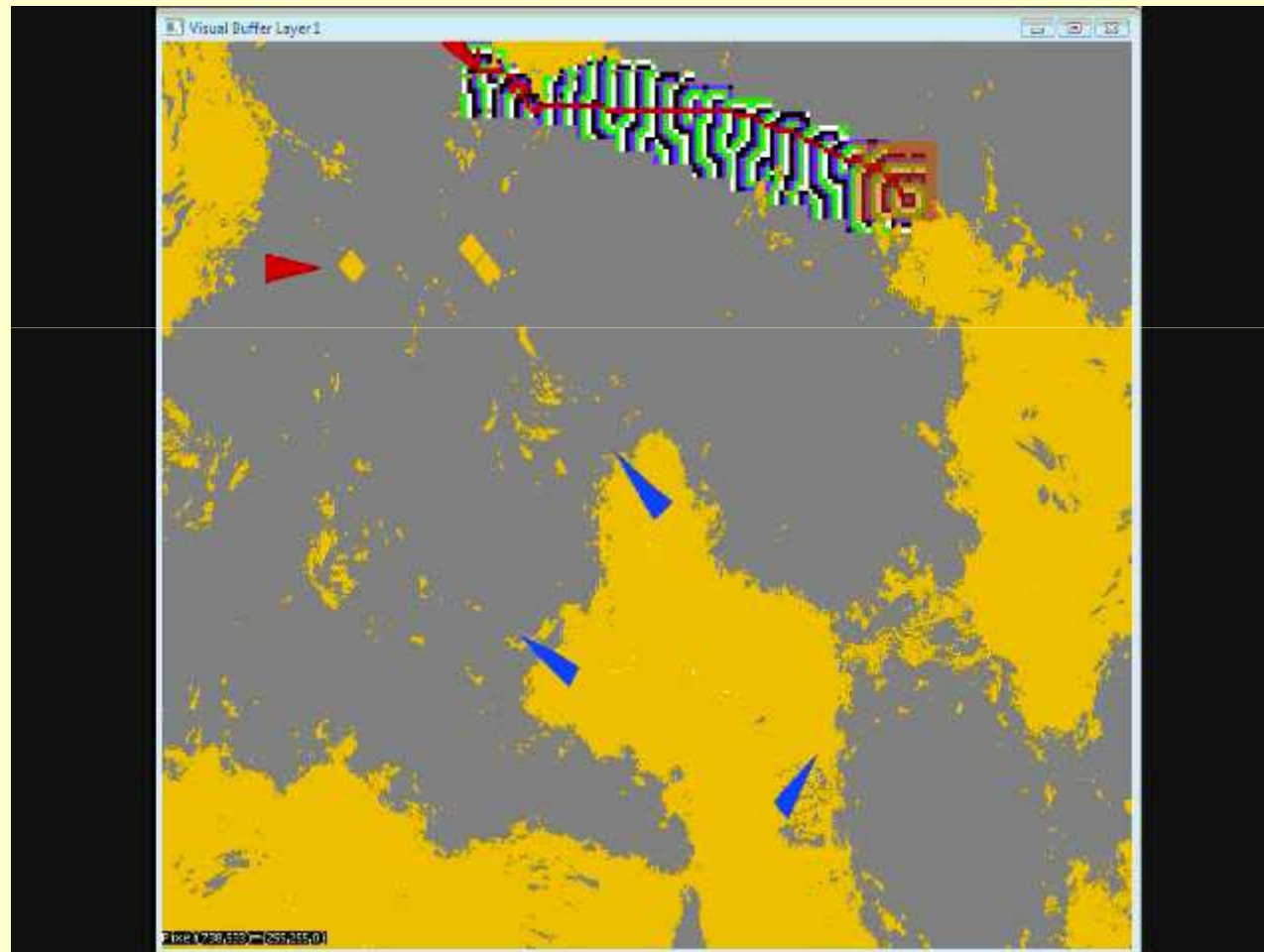




DEPICTIVE MANIPULATIONS (Soar+SVI)



(VIDEO)

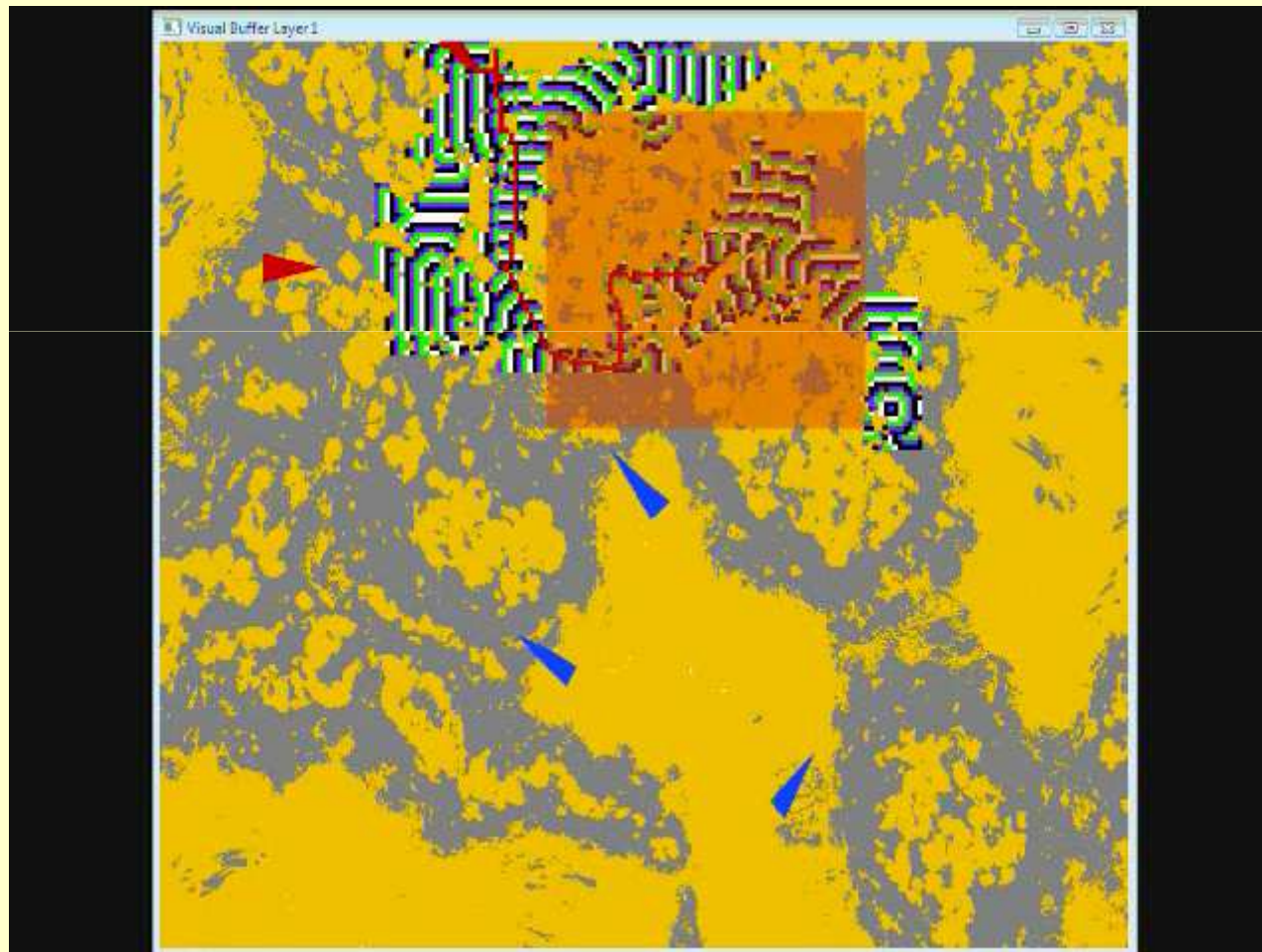




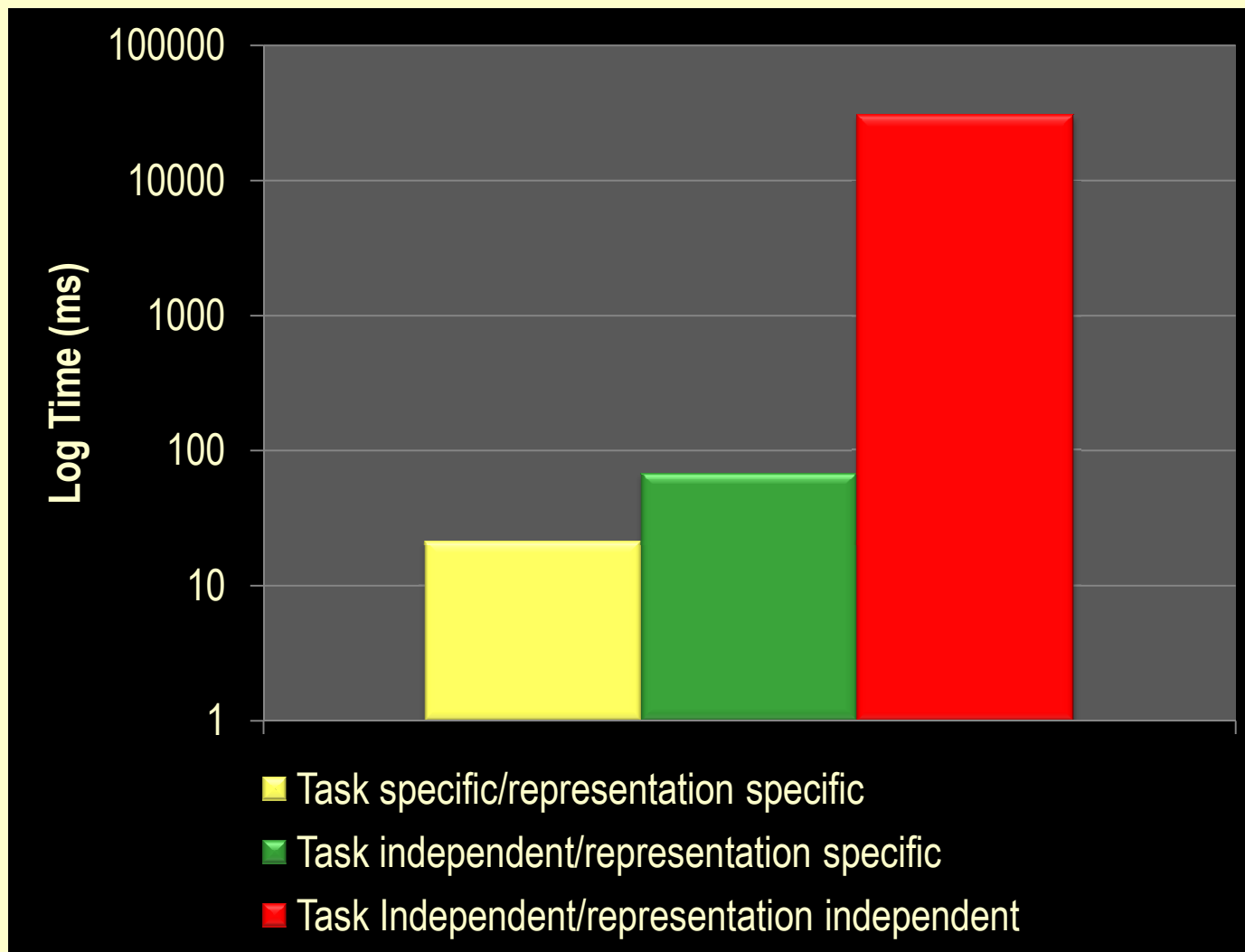
DEPICTIVE MANIPULATIONS (Soar+SVI)



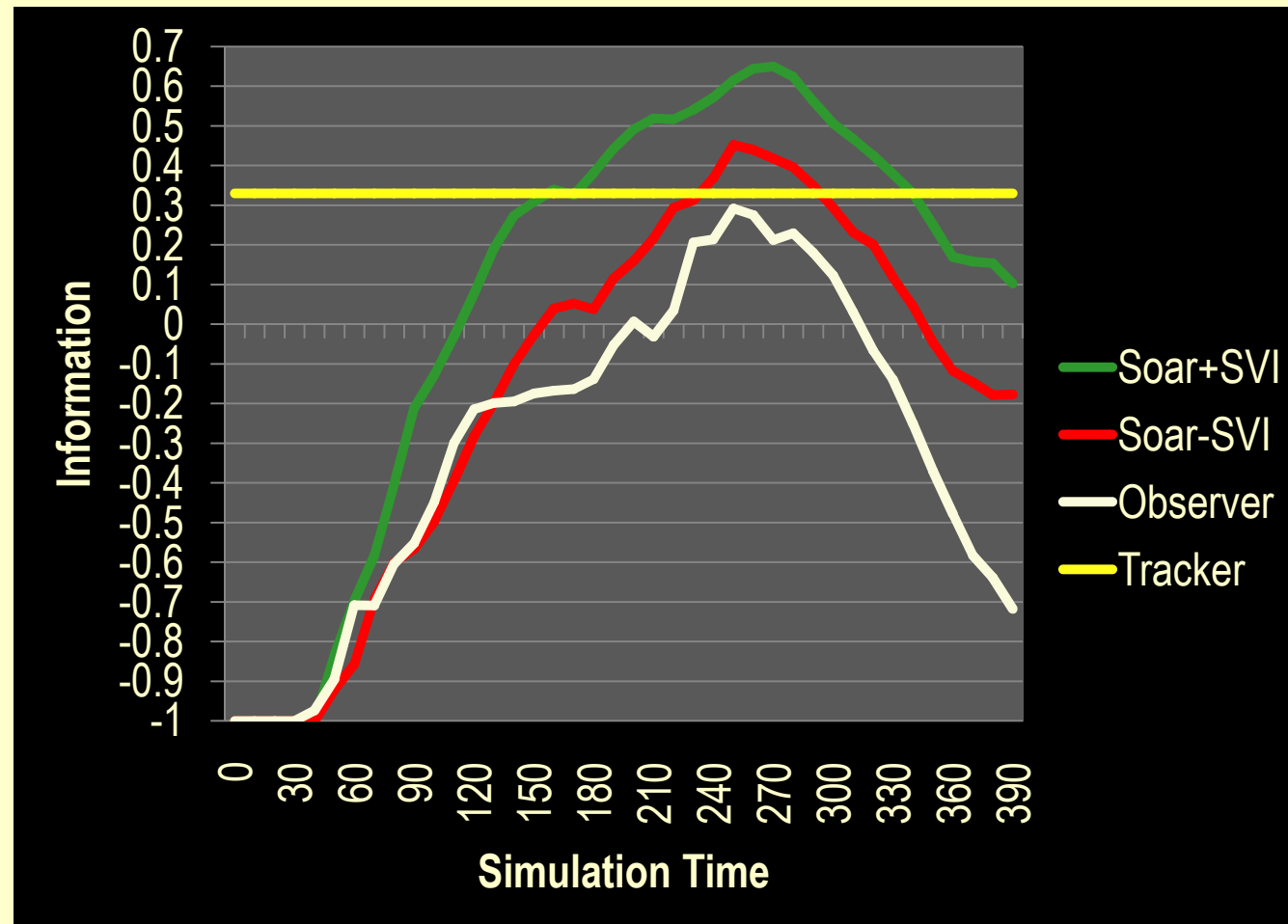
(VIDEO)



COMPUTATIONAL EFFICIENCY



PROBLEM-SOLVING QUALITY



$$I_t = \begin{cases} -1 & \text{if no observation} \\ 1 - \delta & \text{otherwise} \end{cases}$$

$$\delta = \frac{\sqrt{(obs_x - act_x)^2 + (obs_y - act_y)^2}}{d_{acceptable}}$$

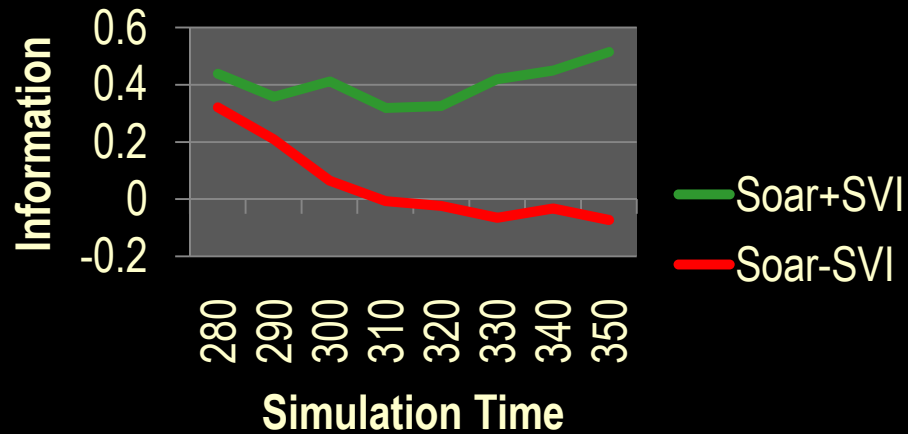
$d_{acceptable}$ = the acceptable square distance = $\sqrt{d_x^2 + d_y^2}$ where $d_x = d_y = 500$ meters



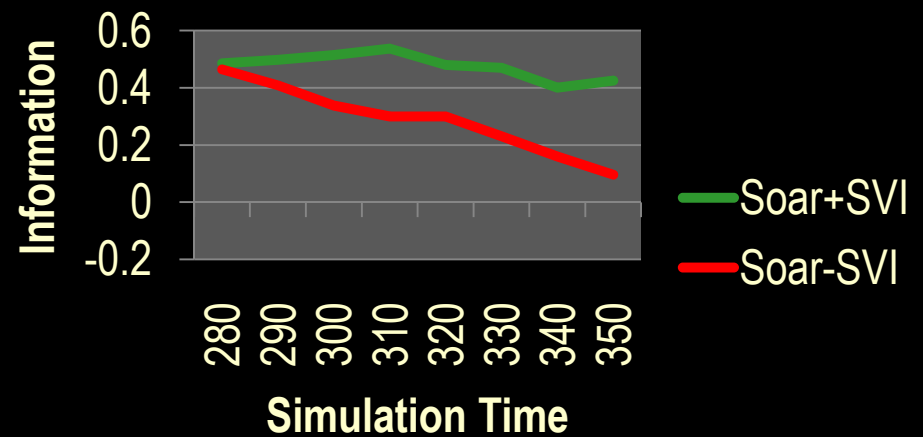
PROBLEM-SOLVING QUALITY (Scenario-2)



Enemy Scout-1 Information



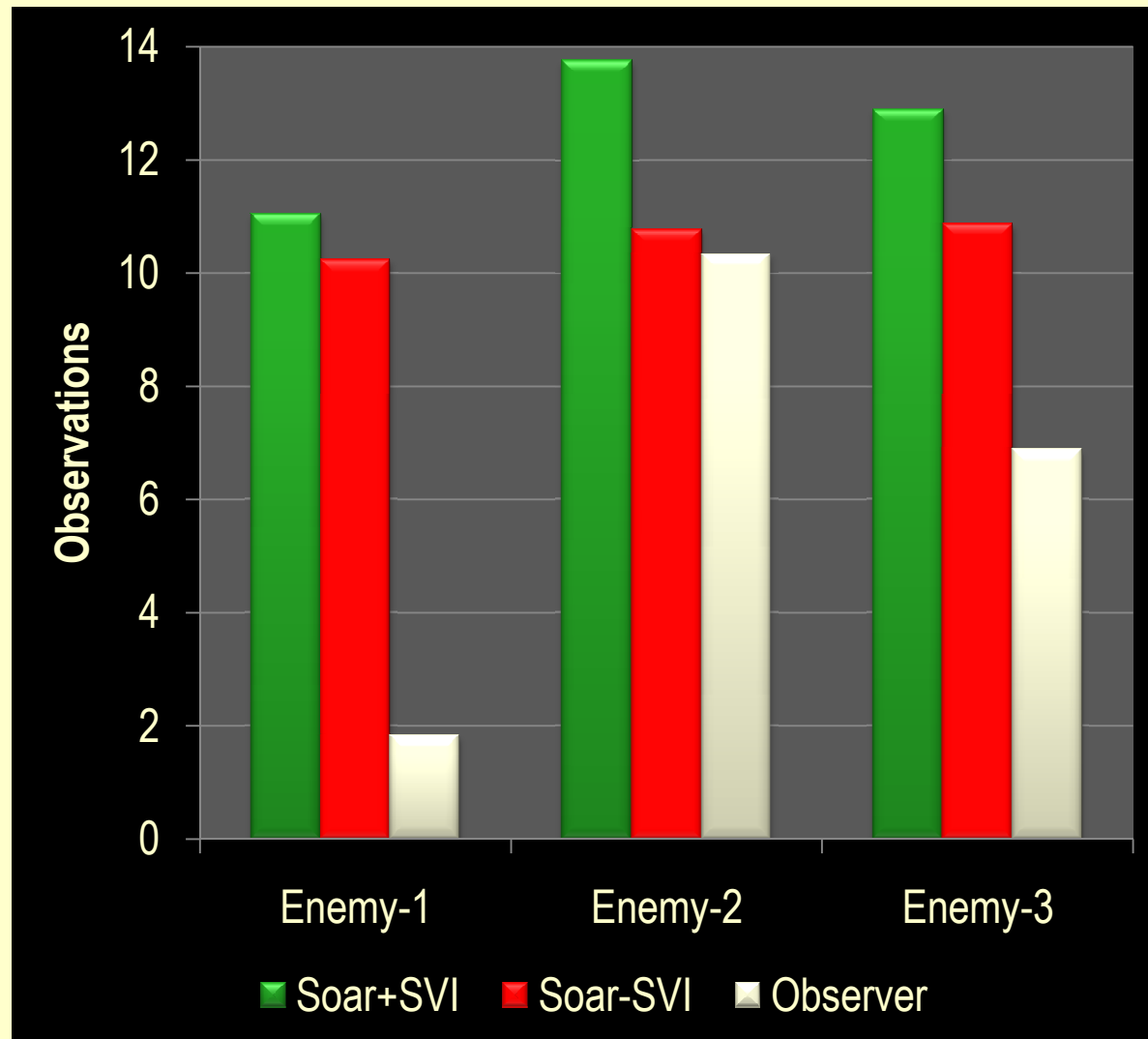
Enemy Scout-3 Information





PROBLEM-SOLVING QUALITY

TOTAL OBSERVATIONS



NUGGETS & COAL

- **NUGGETS**

- Usefulness of reasoning with visual depictive representation and specialized processing
- Integration of spatial and visual imagery functional constraints
 - Task-independent cognitive architecture
 - Reasoning emerges from the combination of the representations

- **COAL**

- More research required on integration between low-level visual perception and system
- Unclear how depictive rules are learned